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OPTIMIZING INTER ROW SPACING IN SUGARCANE BASED INTERCROPPING SYSTEMS IN SEMI-ARID REGIONS OF KARNATAKA

SEEMANTINI NADIGER[1], C. S. HUNSHAL[2] & B. SUNDARA[3]

[1]*Assistant Professor of Agronomy, Dr. D. Y. Patil, College of Agriculture, Talsande, Maharashtra, India*

[2]*Former Dean (PGS), University of Agricultural Sciences, Dharwad, Karnataka, India*

[3]*Former Director, K. J. Somaiya Institute of Applied Agricultural Research (KIAAR), Sameerwadi, Karnataka, India*

ABSTRACT

A field experiment, 'Optimizing inter row spacing in sugarcane based intercropping systems in semi-arid regions of Karnataka were conducted during 2013-14 and 2014-15 at KIAAR, Sameerwadi, Karnataka. The experiment consisted of 12 treatments in plant cane and 23 in ratoon cane. There were three row spacings i.e., 1.2 m, 2.4 m (paired row) and 3.6 m (paired row) and three intercrops (soybean, green pea and drill sown onion) in plant cane and two intercrops (watermelon and cucumber) in ratoon cane. In the plant cane, a significantly higher number of millable canes (NMC) (1,34,717 ha-1), cane yield (110 t ha-1) and CCS yield (14.9 t ha-1) at harvest were recorded in sugarcane at 1.2 m row spacing than at 2.4 m or 3.6 m spacing. In the ratoon cane also, NMC (1,00,953 ha-1), cane yield (67 t ha-1) and CCS yield (7.8 t ha-1) were significantly higher at 1.2 m row spacing compared to 2.4 m and 3.6 m row spacings respectively. Sugarcane at 1.2 m + green pea and onion were the best intercropping systems compared to other intercropping systems in plant cane where as sugarcane at 1.2 m + green pea followed by (fb) watermelon was the best intercropping system compared to others in ratoon cane. In case of total productivity of both plant and ratoon crops, sugarcane at 1.2 m + green pea fb ratoon + cucumber produced higher combined cane yield (187 t ha-1) with 9 q ha-1 of green pea and 44 q ha-1 of cucumber compared to other intercropping systems.

KEYWORDS: Sugarcane, Intercropping, Wide Row, Soybean & Watermelon

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Original Article

INTRODUCTION

Sugarcane (*Saccharum* spp. hybrid complex) is an important commercial crop producing 78 per cent of the world sugar. India ranks second in area and production, after Brazil. During 2015-16, sugarcane was grown over an area of 4.95 million ha with a production of 352.16 million tonnes at a productivity of 71.1 t ha^{-1} (Anon., 2016). In India, Karnataka state stands third in cane production next to Uttar Pradesh and Maharashtra and second in sugar recovery after Maharashtra. Sugarcane is grown in 16 districts of the State. Belgaum, Bagalkot, Bijapur, Mandya, Mysore, Chamrajnagar and Bidar are the major sugarcane producing districts. In Karnataka, sugarcane is cultivated in 4,50,000 ha with the production of 38.48 million tonnes with a productivity of 85.5 t ha^{-1} during 2015-16 season. The total cane crushed in the state during 2015-16 was 37.72 million tonnes, compared to cane crushed during 2014-15 (44.64 million tonnes), a deficit of 15.50 per cent crushing noticed during 2015-16 in the state(Anon., 2016). The sugarcane yield in the North–West Karnataka region has reduced drastically as there was no water in the Malaprabha left bank canal due to failure of rainfall during 2015. Moreover, the farmers could

not lift the required water from the bore well as the power supply was only for 3-4 hours every day. Successive droughts and depleting water sources are factors which are prompting some of the traditional sugarcane farmers to abandon growing of sugarcane.

Hence, to increase the productivity of sugarcane in this region, agronomic measures that reduce the cost of cultivation and improve productivity should be adopted. In this region, most of the farmers are growing sugarcane in 1.2 m spacing and some adopt still wider rows. The space required by the plants is critical for providing proper nutrition, water and light. Therefore, it is essential that suitable and effective crop geometry is evolved by suitable planting techniques (Ehsanullah *et al*., 2011). In sugarcane growing, the human labour costs constitute more than 50 per cent of the total cost of production. Mechanization of cane cultivation is the need of the hour to reduce labour demand. Growing sugarcane in wide rows (> 1.5 m) provides ample scope for intercropping of short duration crops like onion, green pea, soybean, cucumber and watermelon, which enable the farmers to earn additional income. Keeping these aspects in view, the present investigation was carried out at K. J. Somaiya Institute of Applied Agricultural Research (KIAAR), Sameerwadi, Karnataka.

MATERIAL AND METHODS

The field experiment was conducted in Kesarkoppa farm of KIAAR, Sameerwadi, located at 16^0 19' N latitude and 75^0 69' E longitude, at an altitude of 541 m above mean sea level. KIAAR, Sameerwadi comes under Northern Dry Zone of Karnataka (Zone No. 3).During 2013-14 season, the crop received 118.5 mm rainfall during the germination and establishment stage (0-35 days), 195 mm rainfall during the tillering stage (40-120 DAP), there was no rainfall during grand growth stage (120-270 DAP) of the crop and 510.9 mm of rainfall occurred during ripening and maturation stage (270- 545 DAP). The total rainfall of 824.4 mm was received during the entire 18 months crop growth period.

During 2014-15 (ratoon crop), no rainfall was received during sprouting and establishment stage (0-35 days), whereas during the tillering stage (40- 120 DAP) the crop received 28.80 mm rainfall and 275.3 mm of rainfall was received during grand growth stage (120-270 DAP). During ripening and maturation phase (270-330 DAP) 62 mm rainfall was received. The entire ratoon crop received 366.1 mm of rainfall. The soil at the experimental site was medium deep black. The soil was texturally classified as sandy silt loam, with slightly alkaline in pH, medium in available nitrogen (200kg N ha^{-1}), high in available phosphorus (53kg P_2O_5 ha^{-1}) and potassium (750kg K_2O ha^{-1}) and medium in soil organic carbon content (0.65 %). Maize was the preceding crop at the experimental site. The details of the experiment are provided in Tables 1 and 2.

In single rows, the 'V' shaped furrows were formed at a spacing of 1.2 m to a depth of 25 cm. In paired row system, a pair of 'V' shaped furrows were opened at 30 cm space between the rows, with a furrow depth of 25 cm and such pairs were spaced at 2.4 m and 3.6 m apart, giving a paired row spacing of 2.4-0.3-2.4 m and 3.6-0.3-3.6 m. At the time of planting cane setts, full doses of phosphorus (75 kg ha^{-1}), potash (190 kg ha^{-1}), zinc sulphate (25 kg ha^{-1}) and ferrous sulphate (25 kg ha^{-1}) along with 10 per cent of the recommended nitrogen (25 kg ha^{-1}) were applied in the form of diammonium phosphate (DAP), muriate of potash (MOP) and urea respectively by manual application. The sugarcane crop was top dressed with 50, 75 and 100 kg nitrogen per hectare at 6^{th}, 10^{th} and 14^{th} weeks after planting respectively through fertigation. The recommended doses of fertilizers were applied to the intercrops *viz.* soybean, green pea by manual application. Fertilizers were mixed thoroughly and covered with soil at the time of sowing whereas for drill sown onion, 50 per cent of the total nitrogen and full doses of phosphorus and potash were applied at sowing in furrows by mixing with the

soil and remaining 50 per cent nitrogen was top dressed at 30 days after sowing (DAS). The details are furnished in Table 2. During ratoon, since the intercrops *viz.* cucumber and watermelon were sown along the drip lines, the nitrogen was applied through fertigation.

Seed material was selected from the sugarcane crop (cv. Co 86032) grown for seed purpose. The crop was harvested and two budded setts were prepared for planting. The setts were planted in normal method at 1.2 m spacing and in paired row system in 2.4 m and 3.6 m spacing. The seed rate for 1.2 m and 2.4 m spacing was 41,667 two eye budded setts per hectare. The seed rate for 3.6 m row spacing is 27,778 two eye budded setts per hectare. The setts were placed at a depth of 5 cm into the wet soil. At 4-5 days of planting of sugarcane, the seeds of intercrops *i.e.*, soybean, green pea and drill sown onion were dibbled in normal method of planting in furrows. In ratoon cane, watermelon and cucumber were planted along the drip lines. The details regarding date of planting, seed rate is furnished in Table 2. The intercrops in sugarcane *viz.*, soybean, green pea and drill sown onion were sown in row proportion of 1:4 in 1.2 m row spacing of sugarcane, 2:7 in 2.4 m row spacing (paired rows) and 2:10 in 3.6 m row spacing (paired rows). Since soybean suppressed sugarcane emergence, gap filling of sugarcane was carried out in sugarcane intercropped with soybean plots. The three months old tissue cultured sugarcane settlings of variety Co86032 were gap filled after the harvest of soybean.

After the harvest of the plant cane, stubbles above the ground level were shaved within one week. The hard and compact mass of soil near the root zone was loosened by passing a bullock-drawn plough. Gaps in ratoon were filled with single eye bud seedlings raised in poly bags thus achieving the desired plant population. In the ratoon crop, cucumber was sown as an intercrop in the row proportion of 1:1 in 1.2 m row spacing of sugarcane, 2:2 in 2.4 m row spacing (paired rows) and 2:3 in 3.6 m row spacing of sugarcane (paired rows). Intercrop watermelon was sown in the row proportion of 2:1 in 1.2 m row spacing of sugarcane, 2:2 in 2.4 m and 3.6 m row spacings (paired rows).

Sowing of intercrops *i.e.*, cucumber and watermelon were carried out on 25th and 26th of January, 2015. The seeds of these intercrops were dibbled along the drip lines of sugarcane. The details are provided in Table 2. Since the seeds of intercrops were sown along the drip lines in sugarcane, no separate irrigation was provided to intercrops. The trash of previous cane was spread evenly in between the rows of the ratoon crop at 120 DAP after the harvest of intercrops. Fertilizer doses, irrigation and other cultural practices were carried out as in the plant crop. Observations on ratoon cane were recorded same as that of plant crop. The plant cane was harvested after 18 months of planting and the ratoon was harvested at 12 months (Table 2). Fresh tender pods of green pea were harvested two times at 45 and 60 DAS. The green pea crop residue was incorporated into the soil between the sugarcane crop rows. Soybean was harvested at 110 DAS and drill sown onion was harvested at 120 DAS. In ratoon crop tender fruits of cucumber were harvested in seven pickings at an interval of three days. The first harvesting started at 45 DAS. In ratoon crop, watermelon was harvested at 120 DAS.

RESULTS AND DISCUSSIONS

Plant Cane (2013-14)

Sugarcane yield was significantly higher at 1.2 m spacing (110 t ha^{-1}) compared to 2.4 m (89 t ha^{-1}) and 3.6 m (69 t ha^{-1}) row spacings (Table 3). Cane yield is a function of the number of millable canes (NMC), internodal length and number, cane diametre and single cane weight at harvest. In this study, the NMC at harvest was significantly higher in sugarcane at 1.2 m spacing (1,34,717 ha^{-1}) compared to 2.4 m (98,909 ha^{-1}) and 3.6 m (81,114 ha^{-1}) row spacings. This could be attributed to more efficient utilization of moisture, nutrients and solar energy with less inter and intra plant competition in sugarcane grown at 1.2 m spacing. The results are in agreement with Patel *et al*. (2014b) where plant

geometry of 1.2 m normal row spacing found superior in an increasing number of internodes, cane length, number of millable canes and cane yield as compared to 0.90 m, 1.5 m and 1.5-0.3-1.5m row spacing. These results conform the findings of Patel *et al*. (2014a) and Zafar *et al*. (2010). Sagoo *et al*. (2010) also noted that higher cane yield at 0.9-0.3-0.9 m paired row planting pattern was due to improved air circulation and light interception which improved photosynthetic efficiency, increased number of millable canes and improved individual cane weight. Too much increase in inter spacing as in 1.2-0.3-1.2 m paired row planting pattern, number of strips per plot decreased and to maintain equal plant population per plot in all treatments, number of plants per unit area were increased by decreasing plant to plant distance. Hence, inter plant competition increased causing adverse effects on individual cane weight.

The three intercrops [soybean, green pea and drill sown onion] had different growth patterns and canopies. Soybean was fast in growth and covered the ground much earlier, thus inhibiting the emergence of sugarcane and further restricting the growth compared to other two intercrops. Due to this, a large number of gaps were noticed. However, the gaps were filled by transplanting 90-day old sugarcane settlings after the harvest of soybean. By the end of the crop growth, these settlings had made their growth as compared to the sugarcane grown with other two intercrops (Green pea and drill sown onion) thus producing similar yields in all the treatments. Another reason due to which sugarcane in soybean could compensate its growth was because of long duration (400days) available for growth (Totally 545 days i.e., 18 months). The earlier setback in growth was compensated at later stages of growth.

With reference to different intercropping systems, there was no significant difference between sugarcane yields, NMC and single cane weight of sole sugarcane and sugarcane grown with different intercrops (soybean, green pea and drill sown onion) (Table 3). However, intercropping with green pea recorded higher cane yield (96 t ha^{-1}) compared to sugarcane intercropped with drill sown onion (88 t ha^{-1}), soybean (84 t ha^{-1}) and sole sugarcane (89 t ha^{-1}). It was observed that the intercrops drill sown onion and green pea did not affect the growth and yield of sugarcane. This might be due to non-exhaustive and dwarf nature of the intercrop (drill sown onion) and residual effect of the additional fertilizers as well as cultural practices and irrigation applied to intercrops grown with sugarcane (Hossain *et al*. 2003). Compared to other crops, drill sown onion exerted a least detrimental effect on the emergence, shoot growth, millable cane and yield of sugarcane (Hossain 1984). The results are also in conformity with Saini *et al*. (2003) who demonstrated that intercropping of vegetable pea did not affect the cane yield, instead there was a slight improvement over the pure cane. But in case of cane + soybean intercropping, soybean suppressed the growth of sugarcane due to its high canopy coverage. This resulted in the low emergence of sugarcane. After harvest of the soybean at 110 DAP, the sugarcane plot was gap-filled with 90 days old settlings which attained better growth and hence there was no significant difference between yield, NMC and single cane weight of sole sugarcane and sugarcane grown with soybean.

With regard to intercrops [soybean, green pea and drill sown onion], the mean grain yield of soybean (20 q ha^{-1}), pod yield of green pea (10 q ha^{-1}) and bulb yield of drill sown onion (64 q ha^{-1}) were higher in their respective sole crops compared to the yields obtained in intercropping system. This was because of a higher plant population of soybean, green pea and drill sown onion in sole plots compared to 84, 75 and 79 per cent in sugarcane at 1.2 m, 2.4 m and 3.6 m spacings (Table 4). Since drill sown onion needs more underground space for better development of bulbs, the interspecific competition for water, space and nutrients between cane and drill sown onion may be the reason for lower bulb weight and diametre compared to a sole drill sown onion. The results are in accordance with Li *et al*. (2015) that the dry weights of tubers and stems of intercropped cassava with sugarcane decreased by 29.8 and 34.5 per cent respectively, compared to

those of mono-cropped cassava.

Ratoon Cane (2014-15)

The ratoon sugarcane yields were reduced more than 50 per cent compared to plant crop. The main cause for lower yields in ratoon was drought. During 2014-15 season, initially there was no rainfall during sprouting stage (January, 2014). During tillering stage (March-May 2014), the crop received only 28.80 mm rainfall. The crop was supplied with drip irrigation, but it was too inadequate because of shortage of water in the tube wells. Due to severe moisture stress, the cane was there was a heavy infestation of root grub at 120 DAP. Because of these two reasons, the sugarcane ratoon yield was reduced drastically.

Similar to plant cane results, in ratoon cane, the sugarcane yield and number of millable canes (NMC) were significantly higher at 1.2 m row spacing (67 t ha^{-1} and 100953 ha^{-1}, respectively) compared to 2.4 m (45 t ha^{-1} and 80676 ha^{-1}, respectively) and 3.6 m (22 t ha^{-1} and 43790 ha^{-1}, respectively) paired row spacings. In the present study, the space within paired row (2.4 m and 3.6 m spacings) was 0.30 m which was not sufficient for better root establishment of sugarcane. Even though there was more inter row space of 2.4 m and 3.6 m between two paired rows, but the space within the paired row (0.30 m) created severe competition for growth resources especially moisture. Higher planting rates within this spacing have been shown to increase early-season shoot populations, but intra-row competition eliminated many of the shoots during the growing-season. In 1.2 m row spacing, better aeration was available to individual setts compared to 2.4 m and 3.6 m paired row spacing and the growth of sugarcane was better due to better establishment of root system. So, the sugarcane grown at 1.2 m spacing had utilized the soil nutrients and moisture adequately producing higher yields and NMC compared to canes grown at 2.4 m and 3.6 m respectively (Figure 1).

In ratoon cane, the yield level of sugarcane at 2.4 m spacing was reduced by around fifty per cent compared to sugarcane at 1.2 m spacing even though the plant population was same in both the spacings. The inter and intra row plant competitions were severe in paired rows (2.4-0.3-2.4 m and 3.6-0.3-3.6 m) compared to 1.2 m spacing and thus there was a greater reduction in yield compared to 1.2 m leading to lower cane length, dry matter production, cane diametre, number of internodes, internodal length and single cane weight at harvest (Table 5 and 6). Higher shoot mortality in widely spaced paired rows may be because of less inter row and intra row spacing of 0.30 m within the paired rows leading to higher competition between shoots for moisture and nutrients. So, the NMC was significantly lower in wide paired rows compared to 1.2 m spacing.

During drought condition in ratoon cane, the quality parameters of sugarcane (pol %, purity % and CCS %) grown at 2.4 m and 3.6 m were significantly reduced compared to sugarcane at 1.2 m spacing. Because, the ratoon cane grown at 2.4 m and 3.6 m suffered from higher moisture stress compared to sugarcane grown at 1.2 m spacing. In paired row spacing, even though the two drip lines were placed, the crop suffered from higher moisture stress compared to cane grown at 1.2 m spacing due to higher competition between individual plants in less space within the paired rows. It is known that the process of sucrose accumulation is intimately related to the growth process of the sugar cane plant. Thus, more rapid the growth of cane less rapid is the sucrose accumulation and vice-versa. Dried crops usually grow faster than normal irrigated ones during the period following the termination of moisture stress and also take comparatively longer time to complete its growth than normal crop. As a result, dried cane stalks especially during early period of maturity phase, had less sucrose accumulation and higher reducing sugars possibly because of predominance of vacuolar acid invertase in growing immature stalks under the influence of favourable growth conditions (Singh and Reddy 1980).

In the present study, the ratoon cane yield, NMC and single cane weight were unaffected by intercrops cucumber and watermelon (Table 6). These two intercrops belong to the family Cucurbitaceae which spread across the ground horizontally. Unlike in plant cane, the ratoon cane grew faster than intercrops. Hence, the ratoon cane was unaffected by the interspecific competition with cucumber and watermelon. Various growth and yield attributes of sugarcane i.e., cane diameter, number of internodes, internodal length, number of shoots, cane length and DMP did not differ significantly at harvest for the reason that neither cucumber nor watermelon imposed any competition for available resources with sugarcane. Hence, the ratoon cane yield did not differ significantly under different intercropping systems. In addition to this, there was no significant effect on the quality parameters of ratoon cane due to different intercrops.

The yield of intercrops (cucumber and watermelon) did not differ from that of the sole crops thus indicating that competition did not exist between the component crops. Even though watermelon and cucumber belong to the same family Cucurbitaceae, they have different growth habits and their duration varies. Cucumber was harvested at 60 days where as watermelon was harvested at 120 days. The yield levels of these two intercrops are also different. The statistical analysis showed that there is no significant difference in the yield of watermelon both under intercropping and sole cropping. However, the sole crop produced a maximum of 127 q ha^{-1}. Among the various spacings, 1.2 m produced a numerically higher yield of watermelon. Similarly, higher yield was obtained in cane at 1.2 m + green pea *fb* watermelon. In case of cucumber, there was hardly any difference in the yield of intercrop cucumber as well as the sole crop. Since the crop being a short duration of 60 days did not face any sort of competition from sugarcane (Table 7).

While considering the total productivity of the sugarcane intercropping systems in both plant and ratoon cane, it can be concluded that sugarcane at 1.2 m + green pea *fb* ratoon + cucumber produced higher combined cane yield along with 9 qha^{-1} of green pea and 44 qha^{-1} of cucumber compared to other intercropping systems (Table 8).The reason may be due to a higher yield of sugarcane with intercrops green pea in plant and cucumber in ratoon crop compared to other intercropping systems.

CONCLUSIONS

Considering the total productivity of the sugarcane-intercrop cropping systems of plant and ratoon crops, it was concluded that 'sugarcane at 1.2 m + green pea followed by ratoon + cucumber' produced higher combined cane yield (187 t ha^{-1}) along with 9 q ha^{-1} of green pea and 44 q ha^{-1} of cucumber compared to other intercropping systems. The present investigation revealed that in the plant crop of short/mid late duration (*Eksali*) variety, 1:2 row proportion (sugarcane: soybean) was optimum for sugarcane growers in Northern Karnataka.

Further, adoption of long duration variety of sugarcane would be more appropriate with suitable intercrops so that the harvest of sugarcane matches with the crushing season. The present study under drip irrigation revealed that the moisture stress occurring during February-March which coincides with tillering stage of the ratoon crop may lead to insufficient cane population resulting in yield decline.

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APPENDIX

Table 1: Details of the Field Experiment

Sl. No.	Particulars	Details				
1	Title of the research	Agronomic manipulations in sugarcane based cropping systems under drip irrigation				
2	Location	Plot No. 121, Kesarakoppa farm, KIAAR, Sameerwadi Tal: Mudhol, Dist: Bagalkot				
3	Season	Plant cane (Adsali) July 2013 to December 2014 Ratoon cane (Eksali) December 2014 to December 2015				
4	Farming situation	Drip irrigated				
5	Number of treatments	Plant cane- 15, Ratoon cane- 23				
6	Replications	Three				
7	Plot size- Gross plot	7.2 m × 14.4 m (Plant Cane) 7.2 m × 7.2 m (Ratoon cane)				
8	Design	Randomized complete block design				
	Row Spacing between Sugarcane	**Net Plot Size in Plant Crop**			**Net Plot Size in Ratoon Crop**	
	1.2 m	5.2 m × 12.0 m			5.2 m × 7.2 m	
	2.4 m (Paired row)	5.2 m × 9.6 m			5.2 m × 7.2 m	
	3.6 m (Paired row)	5.2 m × 7.2 m			5.2 m × 7.2 m	
Ratio of Sugarcane and Intercrops in Different Cropping Systems						
		Plant Cane			**Ratoon Cane**	
Ratio / Spacing		**Sugarcane : Soybean**	**Sugarcane : Green Pea**	**Sugarcane : Drill Sown Onion**	**Sugarcane : Cucumber**	**Sugarcane : Watermelon**
1.2 m spacing		100 : 84	100 : 84	100 : 84	100 : 100	100 : 100
2.4 m spacing		100: 75	100: 75	100: 75	100: 100	100: 100
3.6 m spacing		67 : 79	67 : 79	67 : 79	67 : 100	67 : 100

Table 2: Details of Variety, Row Arrangement, Date of Sowing, Seed Rate and Fertilizer Application to Sugarcane and Intercrops

Sl. No.	Crops	Name of the Variety/Hybrid	Row Proportion of Sugarcane and Intercrops			Date of Planting/ Sowing	Date of Harvesting	Row Spacing for Intercrops	Seed Rate ha^{-1}	Fertilizers (kg ha^{-1})		
			1.2 m	2.4 m (Paired row)	3.6 m (Paired row)					N	P_2O_5	K_2O
1	Sugarcane (Plant crop) Ratoon crop	CO86032	-	-	-	12/07/2013 30/12/2014	06/12/2014 26/11/2015	-	8 tha^{-1} (2 eye budded setts)	250	75	190
2	Soybean	JS9305	1:4	2:7	2:10	16/07/2013	22/10/2013	30 cm × 10 cm	62.5 kg	40	80	25
3	Green pea	AP3	1:4	2:7	2:10	17/07/2013	26/08/2013	30 cm × 10 cm	30 kg	25	50	50
4	Drill sown onion	N53	1:4	2:7	2:10	17/07/2013	24/11/2013	30 cm × 10 cm	10 kg	125	50	125
5	Cucumber	Belgaum local	1:1	2:2	2:3	25/01/2015	19/03/2015	120 cm × 80 cm	2.5 kg	60	50	80
6	Watermelon	Madhubala	2:1	2:2	2:2	26/01/2015	18/04/2015	240 cm × 80 cm	3.5 kg	55	55	55

Table 3: Plant Cane Yield and Yield Attributes at Harvest as Influenced by Row Spacings and Intercrops

Spacing / Intercrop	Single Cane Weight at Harvest (kg)				Number of Millable Canes ha^{-1}				Sugarcane Yield (t ha^{-1})			
	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean
Sugarcane + Soybean	1.0	1.0	0.9	**1.0**	1,27,353	1,03,459	68,737	**99,849**	108	88	56	**84**
Sugarcane + Green pea	0.9	1.1	1.1	**1.0**	1,40,688	94,296	91,145	**1,08,710**	113	92	82	**96**
Sugarcane + Drill sown onion	0.9	1.0	1.0	**1.0**	1,40,268	89,699	81,597	**1,03,854**	109	81	73	**88**
Sole sugarcane	1.0	0.9	1.1	**1.0**	1,30,561	1,08,185	82,979	**1,07,242**	110	93	63	**89**
Mean	**01.0**	**1.0**	**1.0**		**1,34,717**	**98,909**	**81,114**		**110**	**89**	**69**	
	S.Em. ±		C.D. @ 5 %		S.Em. ±		C.D. @ 5 %		S. Em. ±		C.D. @ 5 %	
Spacing (S)	0.04		NS		3,982		11,678		3.5		10.4	
Intercrops (I)	0.05		NS		4,598		NS		4.1		NS	
S × I	0.09		NS		7,964		NS		7.1		NS	

Table 4: Performance of Intercrops as Influenced by Row Spacings in Plant Cane

Tr. No.	Treatment	Dry Matter Production (g m^{-2})		Intercrop Yield (qha^{-1})	No. of Pods $plant^{-1}$	Pod Weight (g $plant^{-1}$)	100 Grain Weight (g)	Haulm Weight (g $plant^{-1}$)
		30 DAS	60 DAS					
	Soybean							
T_1	Sugarcane at 1.2 m + Soybean (1:4)	27.6	171.8	18	20	9.2	16.6	3.0
T_5	Sugarcane at 2.4 m + Soybean (2:7)	23.5	141.4	17	22	9.7	16.2	2.6
T_9	Sugarcane at 3.6 m + Soybean (2:10)	28.7	162.4	17	18	8.1	16.1	2.3
T_{13}	Sole soybean	29.8	215.4	20	27	11.3	17.5	2.3
	Green Pea							
T_2	Sugarcane at 1.2 m + Green pea (1:4)	20.5	143.9	9				
T_6	Sugarcane at 2.4 m + Green pea (2:7)	20.0	171.4	8				
T_{10}	Sugarcane at 3.6 m + Green pea (2:10)	17.5	111.8	7				
T_{14}	Sole Green pea	21.7	129.3	10				
	Drill Sown Onion				**Single Bulb wt (g)**	**Bulb Diametre (cm)**	**Bulb Length (cm)**	
T_3	Sugarcane at 1.2 m + Drill sown onion (1:4)	0.8	16.1	47	59.5	5.8	4.5	
T_7	Sugarcane at 2.4 m + Drill sown onion (2:7)	0.9	5.4	44	59.8	6.2	5.2	
T_{11}	Sugarcane at 3.6 m + Drill sown onion (2:10)	0.9	19.9	45	62.1	6.3	4.9	
T_{15}	Sole Drill sown onion	0.9	21.0	64	64.5	6.3	5.3	

Table 5: Yield Attributing Parameters of Ratoon Sugarcane at Harvest as Influenced by Row Spacings and Intercrops

Spacing / Intercrop	Number of Internodes				Internodal Length (cm)				Cane Length (cm)				Cane Diameter (mm)			
	At Harvest															
	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean
Soybean in plant cane *fb* cucumber in ratoon	20	18	17	**18**	8.5	7.7	7.3	**7.8**	135	131	122	**130**	26.7	24.2	27.9	**26.2**
Soybean in plant cane *fb* watermelon in ratoon	20	18	18	**19**	9.4	7.8	7.6	**8.3**	148	146	127	**140**	28.3	23.3	24.5	**25.4**
Green pea in plant cane *fb* cucumber in ratoon	19	18	16	**18**	7.9	7.2	7.5	**7.5**	134	139	118	**130**	27.4	23.7	23.3	**24.8**
Green pea in plant cane *fb* watermelon in ratoon	19	19	17	**18**	8.0	7.6	7.5	**7.7**	148	131	117	**132**	28.5	24.1	24.5	**25.7**
Drill sown onion in plant cane *fb* cucumber in ratoon	20	19	18	**19**	8.8	7.8	7.7	**8.1**	144	134	128	**135**	26.3	23.3	23.3	**24.3**
Drill sown onion in plant cane *fb* watermelon in ratoon	21	17	18	**19**	8.4	7.7	7.9	**8.0**	149	148	148	**148**	25.9	24.8	23.1	**24.6**
Sole sugarcane	19	17	19	**18**	8.5	7.1	7.6	**7.7**	141	127	128	**132**	26.9	24.4	23.9	**25.1**
Mean	**20**	**18**	**18**		**8.5**	**7.5**	**7.6**		**143**	**137**	**127**		**27.1**	**24.0**	**24.4**	
	S.Em. ±		C.D. @ 5 %		S.Em. ±		C.D. @ 5 %		S.Em. ±		C.D. @ 5 %		S.Em. ±		C.D. @ 5 %	
Spacing (S)	0.5		1.5		0.2		0.6		3.2		9.3		0.6		1.6	
Intercrops (I)	0.8		NS		0.3		NS		5.0		NS		0.8		NS	
S × I	1.4		NS		0.6		NS		8.6		NS		1.5		NS	

fb- followed by

Table 6: Yield and Yield Attributing Parameters of Ratoon Sugarcane at Harvest as Influenced by Row Spacings and Intercrops

Spacing / Intercrop	No. of Shootsha^{-1}				Number of Millable Canesha^{-1}			
	210 DAP							
	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean
Soybean in plant cane *fb* cucumber in ratoon	98,958	54,591	24,691	**59,413**	1,04,552	81,745	28,806	**71,701**
Soybean in plant cane *fb* watermelon in ratoon	1,00,822	54,237	21,798	**58,952**	1,03,523	85,455	47,068	**78,682**
Green pea in plant cane *fb* cucumber in ratoon	1,09,664	47,518	26,717	**61,299**	1,03,555	77,835	35,944	**72,445**
Green pea in plant cane *fb* watermelon in ratoon	1,16,147	47,196	25,430	**62,925**	98,058	82,240	50,604	**76,967**
Drill sown onion in plant cane *fb* cucumber in ratoon	97,112	57,227	30,125	**61,488**	99,151	75,360	45,685	**73,398**
Drill sown onion in plant cane *fb* watermelon in ratoon	1,08,827	57,387	34,111	**66,775**	93,364	85,712	51,826	**76,967**
Sole sugarcane	94,341	57,401	35,022	**62,255**	1,04,468	76,388	46,596	**75,818**
Mean	**1,03,696**	**53,651**	**28,271**		**1,00,953**	**80,676**	**43,790**	
	S.Em. ±		C.D. @ 5 %		S.Em. ±		C.D. @ 5 %	
Spacing (S)	1885		5387		2706		7736	
Intercrops (I)	2879		NS		4134		NS	
S × I	4986		NS		7161		NS	

fb- followed by

Spacing / Intercrop	Single Cane Weight (kg)				Sugarcane Yield (tha^{-1})			
	210 DAP							
	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean	1.2 m (1:4)	2.4 m (2:7)	3.6 m (2:10)	Mean
Soybean in plant cane *fb* cucumber in ratoon	0.73	0.53	0.67	**0.64**	59	49	17	**42**
Soybean in plant cane *fb* watermelon in ratoon	0.77	0.60	0.50	**0.62**	70	49	22	**47**
Green pea in plant cane *fb* cucumber in ratoon	0.77	0.50	0.57	**0.61**	73	41	18	**44**
Green pea in plant cane *fb* watermelon in ratoon	0.87	0.57	0.53	**0.66**	75	45	21	**47**
Drill sown onion in plant cane *fb* cucumber in ratoon	0.77	0.63	0.57	**0.66**	65	48	25	**46**
Drill sown onion in plant cane *fb* watermelon in ratoon	0.77	0.50	0.43	**0.57**	61	43	24	**43**
Sole sugarcane	0.73	0.60	0.53	**0.62**	64	37	25	**42**
Mean	**0.77**	**0.56**	**0.54**		**67**	**45**	**22**	
	S.Em. ±		C.D. @ 5 %		S.Em. ±		C.D. @ 5 %	
Spacing (S)	0.02		0.05		1.6		4.5	
Intercrops (I)	0.03		NS		2.4		NS	
S × I	0.05		NS		4.2		NS	

fb- followed by

Table 7: Yield of Intercrops in Ratoon Sugarcane

Tr. No.	Treatment	Yield (qha^{-1})
T_{1a}	Sugarcane at 1.2 m + Soybean (1:4) in plant cane *fb* Cucumber (1:1) in ratoon	53.14
T_{2a}	Sugarcane at 1.2 m + Green pea (1:4) in plant cane *fb* Cucumber (1:1) in ratoon	43.85
T_{3a}	Sugarcane at 1.2 m + Drill sown onion (1:4) in plant cane *fb* Cucumber (1:1) in ratoon	40.51
T_{5a}	Sugarcane at 2.4 m + Soybean (2:7) in plant cane *fb* Cucumber (2:2) in ratoon	47.16
T_{6a}	Sugarcane at 2.4 m + Green pea (2:7) in plant cane *fb* Cucumber (2:2) in ratoon	45.78
T_{7a}	Sugarcane at 2.4 m + Drill sown onion (2:7) in plant cane *fb* Cucumber (2:2) in ratoon	44.08
T_{9a}	Sugarcane at 3.6 m + Soybean (2:10) in plant cane *fb* Cucumber (2:3) in ratoon	41.31
T_{10a}	Sugarcane at 3.6 m + Green pea (2:10) in plant cane *fb* Cucumber (2:3) in ratoon	49.96
T_{11a}	Sugarcane at 3.6 m + Drill sown onion (2:10) in plant cane *fb* Cucumber (2:3) in ratoon	56.97
T_{13}	Sole cucumber	59.69
	S.Em. ±	10.1
	C.D. @ 5 %	NS
T_{1b}	Sugarcane at 1.2 m + soybean (1:4) in plant cane *fb* Watermelon (2:1) in ratoon	112
T_{2b}	Sugarcane at 1.2 m + Green pea (1:4) in plant cane *fb* Watermelon (2:1) in ratoon	126
T_{3b}	Sugarcane at 1.2 m + Drill sown onion (1:4) in plant cane *fb* Watermelon (2:1) in ratoon	118
T_{5b}	Sugarcane at 2.4 m + Soybean (2:7) in plant cane *fb* Watermelon (2:1) in ratoon	104
T_{6b}	Sugarcane at 2.4 m + Green pea (2:7) in plant cane *fb* Watermelon (2:1) in ratoon	112
T_{7b}	Sugarcane at 2.4 m + Drill sown onion (2:7) in plant cane *fb* Watermelon (2:1) in ratoon	100
T_{9b}	Sugarcane at 3.6 m + Soybean (2:10) in plant cane *fb* Watermelon (2:2) in ratoon	104
T_{10b}	Sugarcane at 3.6 m + Green pea (2:10) in plant cane *fb* Watermelon (2:2) in ratoon	113
T_{11b}	Sugarcane at 3.6 m + Drill sown onion (2:10) in plant cane *fb* Watermelon (2:2) in ratoon	110
T_{14}	Sole watermelon	127
	S.Em. ±	18.4
	C.D. @ 5 %	NS

fb- followed by

Table 8: Combined Productivity of Sugarcane based Intercropping System During 2013-15

Tr. No.	Treatment	Combined Yield of Sugarcane (Plant + Ratoon) (t ha^{-1})	Soybean Yield (q ha^{-1})	Green Pea Yield (q ha^{-1})	Drill Sown Onion Yield (q ha^{-1})	Cucumber Yield (q ha^{-1})
T_{1a}	Sugarcane at 1.2 m + Soybean (1:4) *fb* Cucumber (1:1) in ratoon	168	18	-	-	53
T_{1b}	Sugarcane at 1.2 m + Soybean (1:4) *fb* Watermelon (2:1) in ratoon	179	18	-	-	-
T_{2a}	Sugarcane at 1.2 m + Green pea (1:4) *fb* Cucumber (1:1) in ratoon	187	-	9	-	44
T_{2b}	Sugarcane at 1.2 m + Green pea (1:4) *fb* Watermelon (2:1) in ratoon	150	-	9	-	-
T_{3a}	Sugarcane at 1.2 m + Drill sown onion (1:4) *fb* Cucumber (1:1) in ratoon	176	-	-	47	41
T_{3b}	Sugarcane at 1.2 m + Drill sown onion (1:4) *fb* + Watermelon (2:1) in ratoon	171	-	-	47	-
T_4	Sole sugarcane at 1.2 m *fb* sole sugarcane at 1.2 m	176	-	-	-	-
T_{5a}	Sugarcane at 2.4 m + Soybean (2:7) *fb* Cucumber (2:2) in ratoon	138	17	-	-	47
T_{5b}	Sugarcane at 2.4 m + Soybean (2:7) *fb* Watermelon (2:1) in ratoon	138	17	-	-	-
T_{6a}	Sugarcane at 2.4 m + Green pea (2:7) *fb* Cucumber (2:2) in ratoon	133	-	8	-	46
T_{6b}	Sugarcane at 2.4 m + Green pea (2:7) *fb* Watermelon (2:1) in ratoon	138	-	8	-	-
T_{7a}	Sugarcane at 2.4 m + Drill sown onion (2:7) *fb* Cucumber (2:2) in ratoon	130	-	-	44	44
T_{7b}	Sugarcane at 2.4 m + Drill sown onion (2:7) *fb* Watermelon (2:1) in ratoon	124	-	-	44	-
T_8	Sole sugarcane at 2.4 m *fb* sole sugarcane at 2.4 m	131	-	-	-	-
T_{9a}	Sugarcane at 3.6 m + Soybean (2:10) *fb* Cucumber (2:3) in ratoon	73	17	-	-	41
T_{9b}	Sugarcane at 3.6 m + Soybean (2:10) *fb* Watermelon (2:2) in ratoon	78	17	-	-	-
T_{10a}	Sugarcane at 3.6 m + Green pea (210) *fb* Cucumber (2:3) in ratoon	101	-	7	-	50
T_{10b}	Sugarcane at 3.6 m + Green pea (2:10) *fb* Watermelon (2:2) in ratoon	104	-	7	-	-
T_{11a}	Sugarcane at 3.6 m + Drill sown onion (2:10) *fb* Cucumber (2:3) in ratoon	99	-	-	45	57
T_{11b}	Sugarcane at 3.6 m + Drill sown onion (2:10) *fb* Watermelon (2:2) in ratoon	98	-	-	45	-
T_{12}	Sugarcane at 3.6 m *fb* sole sugarcane at 3.6 m	89	-	-	-	-

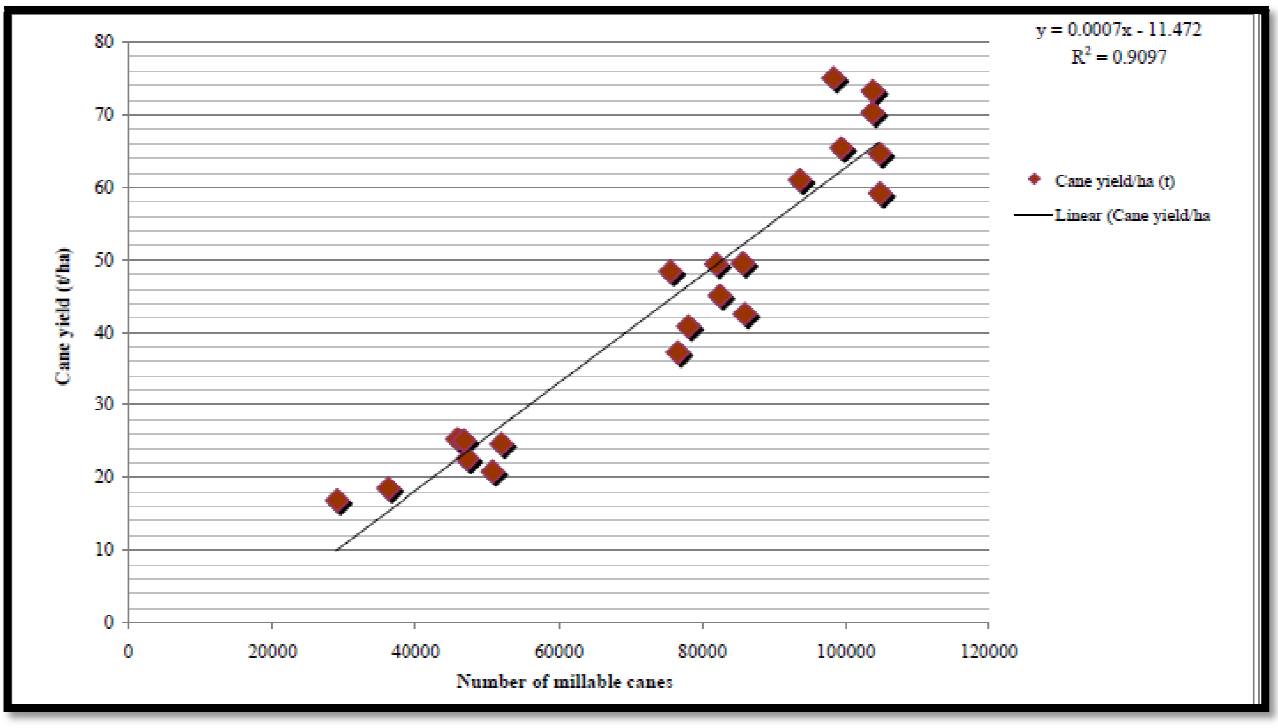

Figure 1: Correlation between Number of Millable Canes and Cane Yield in Ratoon